# Calculating and Explaining Energy Changes

## Question Paper 1

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|---|---|
| **Level** | IGCSE |
| **Subject** | Chemistry (4402) |
| **Exam Board** | AQA |
| **Unit** | C3 |
| **Topic** | Calculating and Explaining Energy Changes |
| **Booklet** | Question Paper 1 |

**Time Allowed:** **60 minutes**

**Score:** **/ 60**

**Percentage:** **/100**

**Grade Boundaries:**

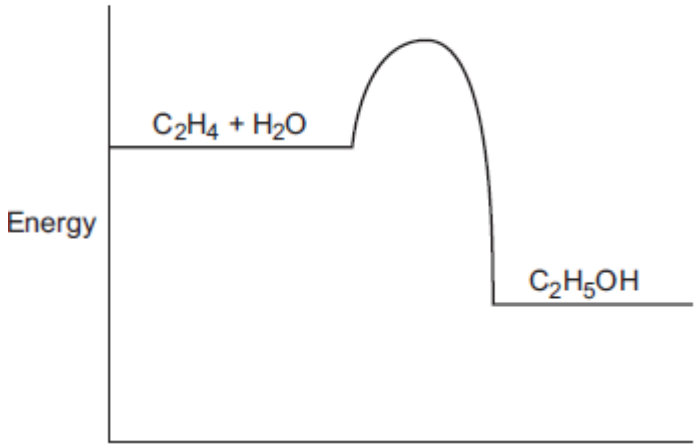
**Q1.**This question is about ethanol.

(a) Ethanol is produced by the reaction of ethene and steam:

$$C_2H_4 + H_2O \longrightarrow C_2H_5OH$$

(i) **Figure 1** shows the energy level diagram for the reaction.

**Figure 1**




How does the energy level diagram show that the reaction is exothermic?

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**(1)**

(ii) A catalyst is used for the reaction.

Explain how a catalyst increases the rate of the reaction.

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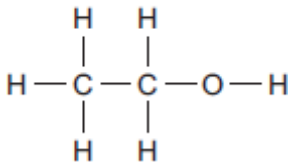
**(2)**

(b) **Figure 2** shows the displayed structure of ethanol.

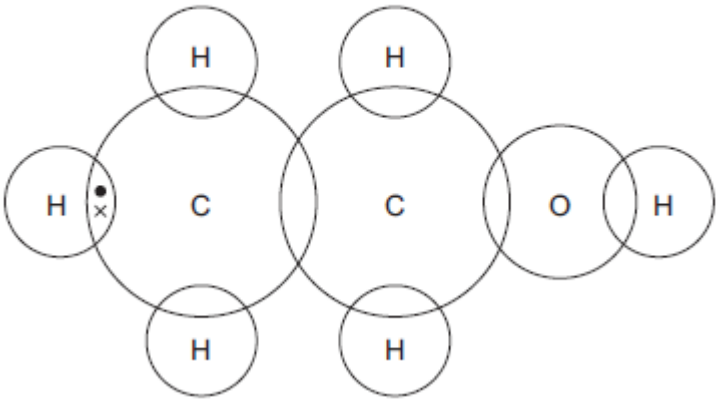
**Figure 2**




Complete the dot and cross diagram in **Figure 3** to show the bonding in ethanol.

Show the outer shell electrons only.

**Figure 3**

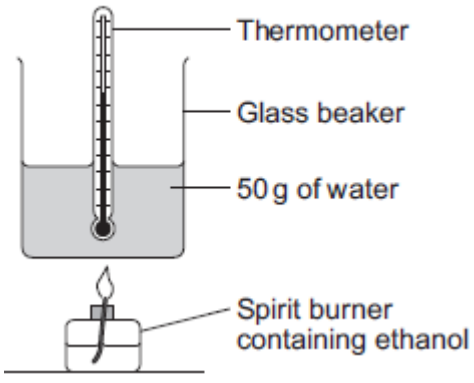



**(2)**

(c) A student burned some ethanol.

**Figure 4** shows the apparatus the student used.

**Figure 4**




(i) The student recorded the temperature of the water before and after heating.

His results are shown in **Table 1**.

**Table 1**

| | |
|---|---|
| Temperature before heating | 20.7 °C |
| Temperature after heating | 35.1 °C |

Calculate the energy used to heat the water.

Use the equation $Q = m \times c \times \Delta T$

The specific heat capacity of water = 4.2 J / g / °C

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Energy used = ..... J

**(3)**

(ii) **Table 2** shows the mass of the spirit burner before the ethanol was burned and after the ethanol was burned.

**Table 2**

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|---|---|
| Mass of spirit burner before ethanol was burned | 72.80 g |
| Mass of spirit burner after ethanol was burned | 72.10 g |

Calculate the number of moles of ethanol ($C_2H_5OH$) that were burned.

Relative atomic masses ($A_r$): H = 1; C = 12; O = 16

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Number of moles burned = .....

**(3)**

(iii) Calculate the energy released in joules per mole.

You should assume that all the energy from the ethanol burning was used to heat the water.

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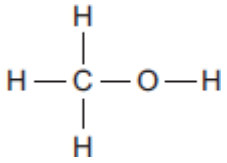
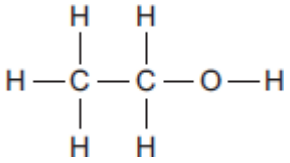
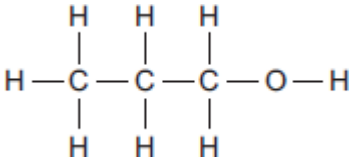
Energy = ..... J / mole

**(1)**

(d) The names, structures and boiling points of ethanol and two other alcohols are shown in **Table 3**.

**Table 3**

| **Name** | **Methanol** | **Ethanol** | **Propanol** |
|---|---|---|---|
| **Structure** |  |  |  |
| **Boiling point in °C** | 65 | 78 | 97 |

Use your knowledge of structure and bonding to suggest why the boiling points increase as the number of carbon atoms increases.

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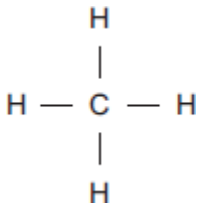
**(3)**
**(Total 15 marks)**

**Q2.** Methane ($CH_4$) is used as a fuel.

(a) The displayed structure of methane is:



Draw a ring around a part of the displayed structure that represents a covalent bond.

**(1)**

(b) Why is methane a compound?

Tick (✓) **one** box.

Methane contains atoms of two elements, combined chemically. ☐

Methane is not in the periodic table. ☐

Methane is a mixture of two different elements. ☐

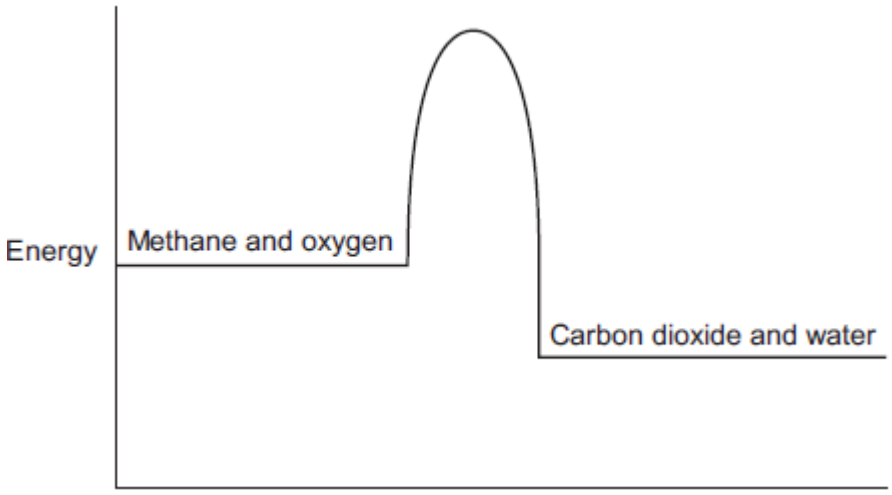
**(1)**

(c) Methane burns in oxygen.

(i) The diagram below shows the energy level diagram for the complete combustion of methane.

Draw and label arrows on the diagram to show:

- the activation energy
- the enthalpy change, $\Delta H$.




**(2)**

(ii) Complete and balance the symbol equation for the complete combustion of methane.

$CH_4$ + ..... ⟶ $CO_2$ + .....

**(2)**

(iii) Explain why the **incomplete** combustion of methane is dangerous.

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**(2)**

(iv) Explain why, in terms of the energy involved in bond breaking and bond making, the combustion of methane is exothermic.

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**(3)**

(d) Methane reacts with chlorine in the presence of sunlight.

The equation for this reaction is:

Some bond dissociation energies are given in the table.

| **Bond** | **Bond dissociation energy in kJ per mole** |
|---|---|
| C−H | 413 |
| C−Cl | 327 |
| Cl−Cl | 243 |
| H−Cl | 432 |

(i) Show that the enthalpy change, *ΔH*, for this reaction is −103 kJ per mole.

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**(3)**

(ii) Methane also reacts with bromine in the presence of sunlight.

This reaction is less exothermic than the reaction between methane and chlorine.

The enthalpy change, $\Delta H$, is −45 kJ per mole.

What is a possible reason for this?

Tick (✓) **one** box.

$CH_3Br$ has a lower boiling point than $CH_3Cl$ ☐

The C−Br bond is weaker than the C−Cl bond. ☐

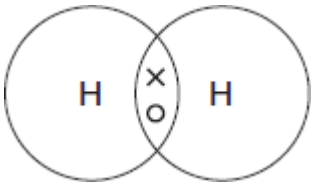
The H−Cl bond is weaker than the H−Br bond. ☐

Chlorine is more reactive than bromine. ☐

**(1)**
**(Total 15 marks)**

**Q3.** Hydrogen gas is produced by the reaction of methane and steam.

(a) The diagram represents a molecule of hydrogen.




(i) What type of bond joins the atoms of hydrogen?

Tick (✔) **one** box.

Covalent ☐

Metallic ☐

Ionic ☐

**(1)**

(ii) A catalyst is used in the reaction.

Draw a ring around the correct answer to complete the sentence.

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|---|---|
| A catalyst | increases the rate of reaction. |
| | increases the temperature. |
| | increases the yield of a reaction. |

**(1)**

(b) The equation for the reaction of methane and steam is:

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

(i) What is meant by the symbol $\rightleftharpoons$ ?

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**(1)**

(ii) Lowering the pressure reduces the rate of reaction.

Explain why, in terms of particles.

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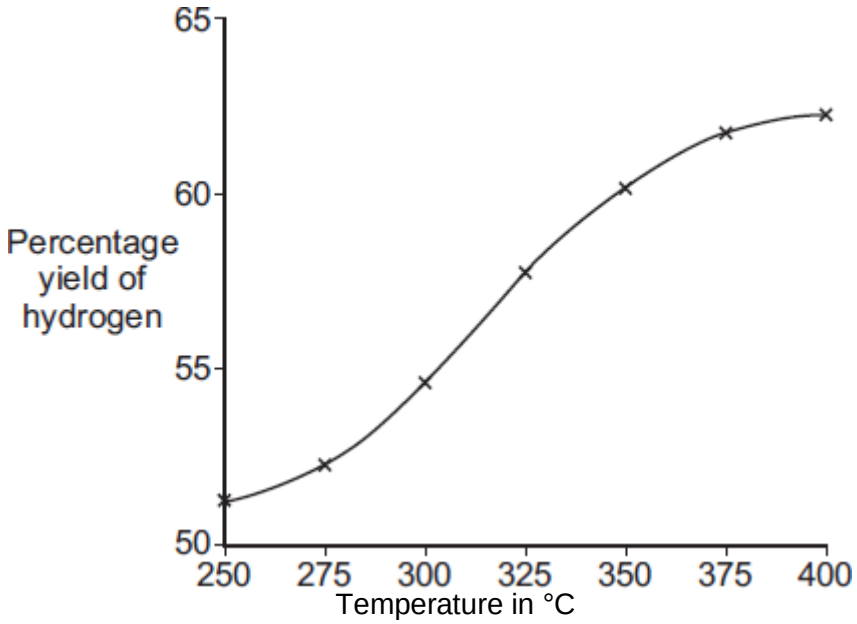
**(2)**

(iii) The graph shows the yield of hydrogen at different temperatures.




The forward reaction is endothermic.

How does the graph show that the forward reaction is endothermic?

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**(1)**

(iv) Why is a higher yield produced if the reaction is repeated at a lower pressure?

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**(1)**

(c) *In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.*

Car engines are being developed that use hydrogen gas as a fuel instead of petrol.

The table compares the two fuels.

| | Hydrogen | Petrol |
|---|---|---|
| Energy | 5700 kJ per litre | 34 000 kJ per litre |
| State | Gas | Liquid |
| Equation for combustion | $2H_2 + O_2 \rightarrow 2H_2O$ | $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ |
| How the fuel is obtained | Most hydrogen is produced from coal, oil or natural gas. Hydrogen can be produced by the electrolysis of water or the solar decomposition of water. | Fractional distillation of crude oil. |

Use the information in the table and your knowledge of fuels to evaluate the use of hydrogen instead of petrol as a fuel.

You should describe the advantages and disadvantages of using hydrogen instead of petrol.

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*Extra space* .....

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**(6)**
**(Total 13 marks)**

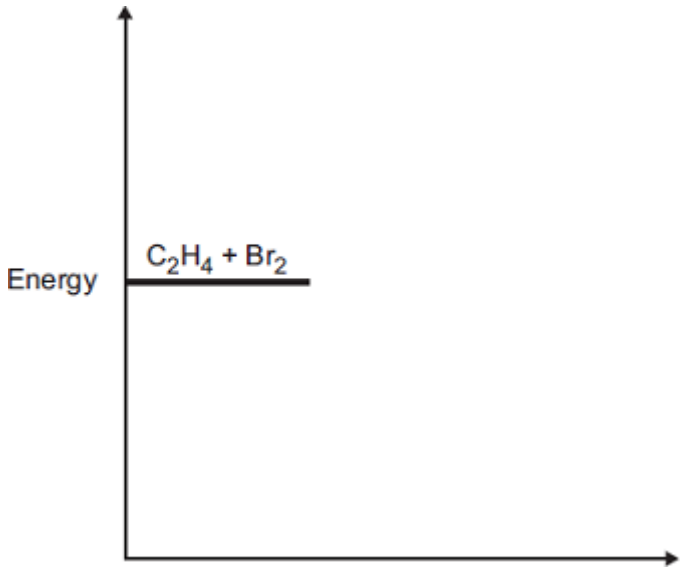
**Q4.** The equation for the reaction of ethene and bromine is:

$$C_2H_4(g) + Br_2(l) \longrightarrow C_2H_4Br_2(l)$$

The reaction is exothermic.

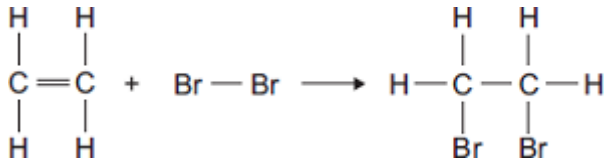
(a) Complete the energy level diagram.

You should label:
- the activation energy
- the enthalpy change ($\Delta H$).




**(3)**

(b) (i) The equation for the reaction can be represented as:



| Bond | Bond dissociation energy in kJ per mole |
|---|---|
| C—H | 413 |
| C = C | 614 |
| Br—Br | 193 |
| C—C | 348 |
| C—Br | 276 |

Use the bond dissociation energies in the table to calculate the enthalpy change ($\Delta H$) for this reaction.

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Enthalpy change ($\Delta H$) = ..... kJ per mole

**(3)**

(ii) The reaction is exothermic.

Explain why, in terms of bonds broken and bonds formed.

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**(2)**
**(Total 8 marks)**

**Q5.** A company manufactures ethanol ($C_2H_5OH$).

The reaction for the process is:

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -45 \text{ kJ per mole}$$

The temperature and pressure can be changed to increase the yield of ethanol at equilibrium.

(a) Explain what is meant by equilibrium.

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**(3)**

(b) (i) How would increasing the temperature change the **yield** of ethanol at equilibrium?

Give a reason for your answer.

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**(2)**

(ii) How would increasing the pressure change the **yield** of ethanol at equilibrium?

Give a reason for your answer.

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**(2)**

(c) A catalyst is added to increase the rate of the reaction.

Explain how adding a catalyst increases the rate of a chemical reaction.

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**(2)**
**(Total 9 marks)**